PUERTO RICO AND VIRGIN ISLANDS PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 42* and *Technical Paper No. 53*

Tenth Progress Report
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Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

TABLE OF CONTENTS

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1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for Puerto Rico and the Virgin Islands. Current precipitation frequency estimates for the area are contained in *Technical Paper No. 42* "Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands" (U.S. Weather Bureau 1961) and *Technical Paper No. 53* "Two- to ten-day rainfall for return periods of 2 to 100 years in Puerto Rico and Virgin Islands" (Miller 1965). The new study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the Puerto Rico and Virgin Island study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14 on the internet using web pages with the additional ability to download digital files.

The study area covers Puerto Rico and the U.S. Virgin Islands of St. Thomas, St. John and St. Croix. The study area is currently divided into 7 homogeneous climatic regions for analysis (Figure 1).

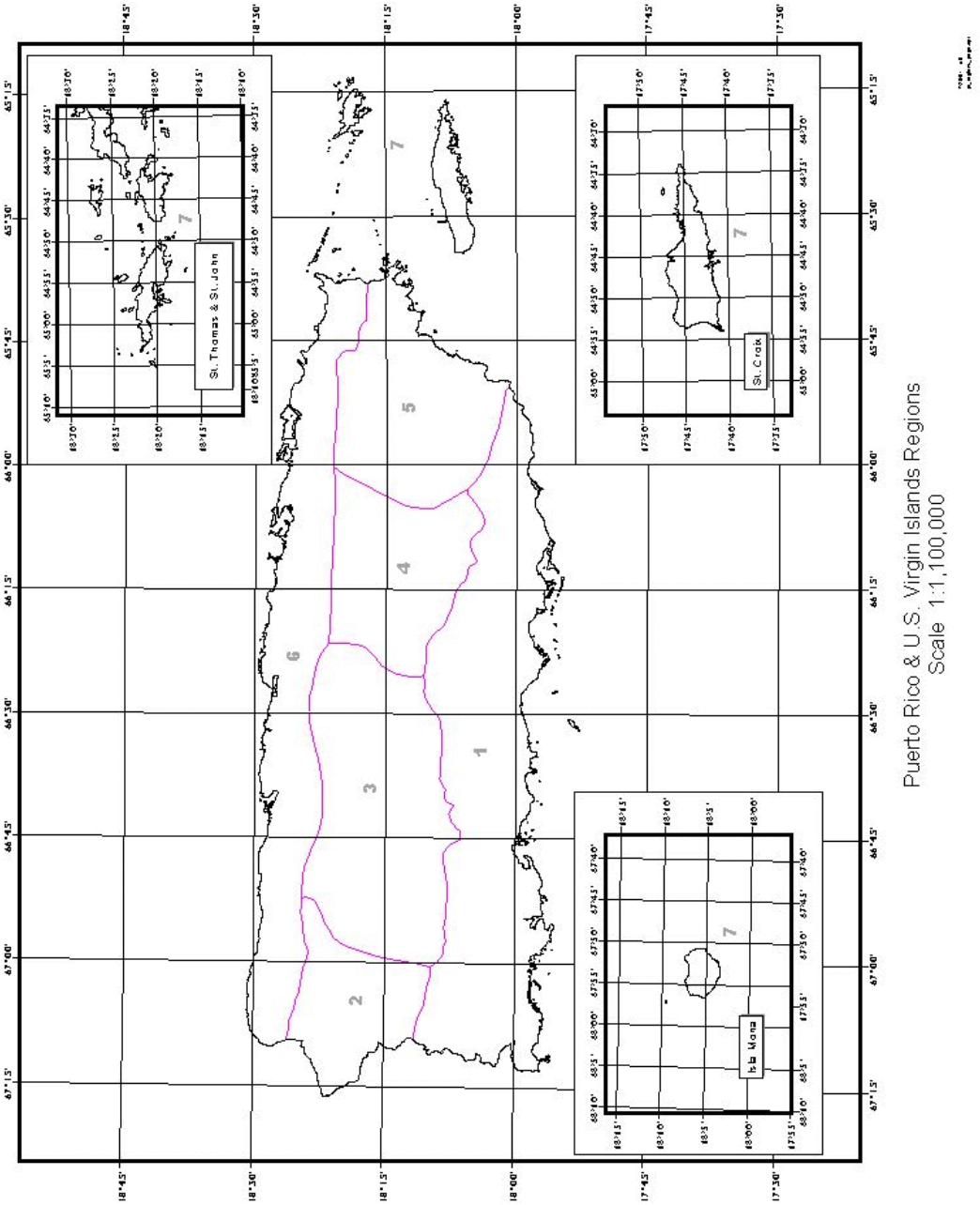


Figure 1. Puerto Rico Precipitation Frequency study area and region boundaries.

2. Highlights

A significant amount of work was completed for the Semiarid study area. This work contributes directly to the development of systems and techniques which will be used in Puerto Rico and the Virgin Islands.

Software was refined and automated to adjust quantiles for co-located hourly and daily data across all durations and frequencies. Software to compute and adjust confidence limits for co-located stations was also written. Software to carry quantile estimates of hourly stations out to 48-hours was completed. Additional information is provided in Section 4.1, Software Updates.

The Spatial Climate Analysis Service (SCAS) delivered a 14-page interim report to HDSC on December 24, 2002 describing the production of the draft 1-hour and 24-hour "index flood" Semiarid rainfall grids using PRISM. A minor change was made to the Cascade, Residual Add-back (CRAB) precipitation frequency grid derivation procedure to prevent multiple filtering as longer return frequencies are generated. Lastly, a final map/grid deliverable list was developed. Additional information is provided in Section 4.2, Spatial Interpolation.

Seasonal information will be presented graphically as percentages of "exceedences" that occur in each month for a given region for 2-year, 10-year, 25-year, 50-year, and 100-year return frequencies. The software for the 1-hour and 24-hour durations has been written and preliminary Semiarid graphs have been incorporated into the Precipitation Frequency Data Server. Additional information is provided in Section 4.3, Seasonal Graphs.

In order to accommodate all of the Precipitation Frequency Data Server and geospatial files, the allocated disk space for the PFDS was increased. The PFDS output was also modified to include "seasonal exceedence graphs." Additional information is provided in Section 4.4, Precipitation Frequency Data Server.

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for areas from 10 to 400 square miles continues. The initial computer programming to quantify the spatial variation of storms used in the D-A-D analysis has been completed and tested successfully on two study areas. The second phase of the programming to perform the actual D-A-D curve fitting is nearly complete. Additional information is provided in Section 4.5, Depth Area Duration Study.

3. Status

3.1 Project Task List

The following checklist shows the components of each task and an estimate of the percent completed per task. Past status reports should also be referenced for additional information.

Puerto Rico study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [90%]:

- Multi-day
- Daily
- Hourly
- 15-minute
- N-minute

L-Moment Analysis/Frequency Distribution for 5 minute to 60 days and 2 to 1000 years [0%]:

- Multi-day
- Daily
- Hourly
- 15-minute
- N-minute

All software to produce the precipitation frequency estimates and associated confidence limits and adjust both for internal consistency is complete.

Spatial Interpolation [0%]:

- Create mean annual maximum (a.k.a. “Index flood”) grids with PRISM for each duration (1-hr, 2-hr, 3-hr, 12-hr, 24-hr, 48-hr, 4-day, 7-day, 10-day, 20-day, 30-day, 45-day, 60-day)
- Apply a precipitation frequency map derivation procedure, known as the cascade residual add-back (CRAB) procedure to create a total of 162 grids. The same procedure will be used to create 162 upper and 162 lower bound precipitation frequency grids.
- Apply study-wide conversion factor to the 60-minute precipitation frequency grids to calculate the n-minute (5-, 10-, 15-, and 30-minute) grids

Peer Reviews [0%]

- Lead review of point precipitation frequency estimates
- Lead review of spatial interpolation grids

Data Trend Analysis [10%]:

- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

Temporal Distributions of Extreme Rainfall [10%]:

- Create graphs of percentage of precipitation maxima in each month of a year
- assemble hourly data by quartile of greatest precipitation amount and convert to cumulative rainfall amounts for each region
- sort, average, and plot time distribution of hourly maximum events for different climatological regions and seasons

Deliverables [45%]:

- Prepare data for web delivery
- Prepare documentation for web delivery
- Write hard copy of Final Report
- Publish hard copy of Final Report

A detailed outline of the final documentation is complete for the Semiarid Study requiring only minor modification for the Puerto Rico Study. The Precipitation Data Frequency Server (PFDS) has been modified to include seasonal graphs.

Spatial Relations (Depth-Area-Duration Study) [60%]:

- Obtain hourly data from dense-area reporting networks
- QC and format data from dense networks
- Compute maximum and average annual areal depth for each duration from stations for each network
- Compute ratio of maximum to average depth for all durations and networks and plot
- Prepare curves of best fit (depth-area curves) for each duration and network

D-A-D reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in a separate volume of NOAA Atlas 14.

4. Progress in this Reporting Period

4.1 Software Updates

Internal consistency software was refined to include all durations and all return frequencies. When internal consistency adjustments are made in the quantiles for one return frequency, it is necessary to adjust all frequencies to maintain realistic results (i.e., so that 50-year estimates are not greater than 100-year estimates). This is particularly true at shorter return frequencies because ratios of small values can be large, leading to large adjustments. Software to carry quantile estimates of hourly stations out to 48-hours was also completed.

Software was created to generate a complete list of co-located hourly and daily stations with their assigned regions and run existing adjustment software on all regions at once with minimal manual input. This provides a more efficient and less error-prone mechanism for completing the precipitation frequency analysis for a given study area. In addition, software to compute and adjust confidence limits for co-located stations was written.

4.2 Spatial Interpolation

The Spatial Climate Analysis Service (SCAS) at Oregon State University delivered a 14-page interim report to HDSC on December 24, 2002. The report describes the work performed to produce the draft 1-hour and 24-hour “index flood” rainfall grids for the Semiarid Southwest study using the PRISM model (Parameter-elevation Regressions on Independent Slopes Model). This production provides the foundation for the Puerto Rico “index flood” rainfall grids. Although the interim report deals with the Semiarid grids, the Puerto Rico grids will essentially be created using the same process. A few adjustments to the PRISM process will be made for the Puerto Rico project, namely to account for coastal effects that the Semiarid project did not have.

A minor change was made to the Cascade, Residual Add-back (CRAB) precipitation frequency grid derivation procedure (see CRAB description in 9th Progress Report, Section 4.3). Instead of using a final, slightly filtered grid as the predictor for the subsequent grid, the CRAB procedure now maintains and uses unfiltered grids for its predictor grids throughout the process. The final grids for each precipitation frequency estimate are still slightly filtered, but because filtering is not done on the predictor grid, a greater level of spatial detail is maintained and portrayed in the resulting grids/maps. Lastly, a final map/grid deliverable list was developed (see Table 1). All durations and return frequencies will have ArcInfo ASCII grids and ESRI shapefiles of isohyets. Initially, a subset of durations and return frequencies will have state-specific printable cartographic maps in PDF format with the remaining durations to be produced as time permits in the future (indicated in table by asterisks).

Table 1. List of all map/grid deliverables.

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr	1000-yr
5-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
10-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
15-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
30-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
60-min	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
120-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
3-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
6-hr	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
12-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
24-hr	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
48-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
4-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
7-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
10-day	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
20-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
30-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
45-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
60-day	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*

G = ArcInfo ASCII grid
S = ESRI shapefile of isohyets
SM = State-specific printable cartographic map (PDF format)
SM* = State-specific printable cartographic map (PDF format) as time permits

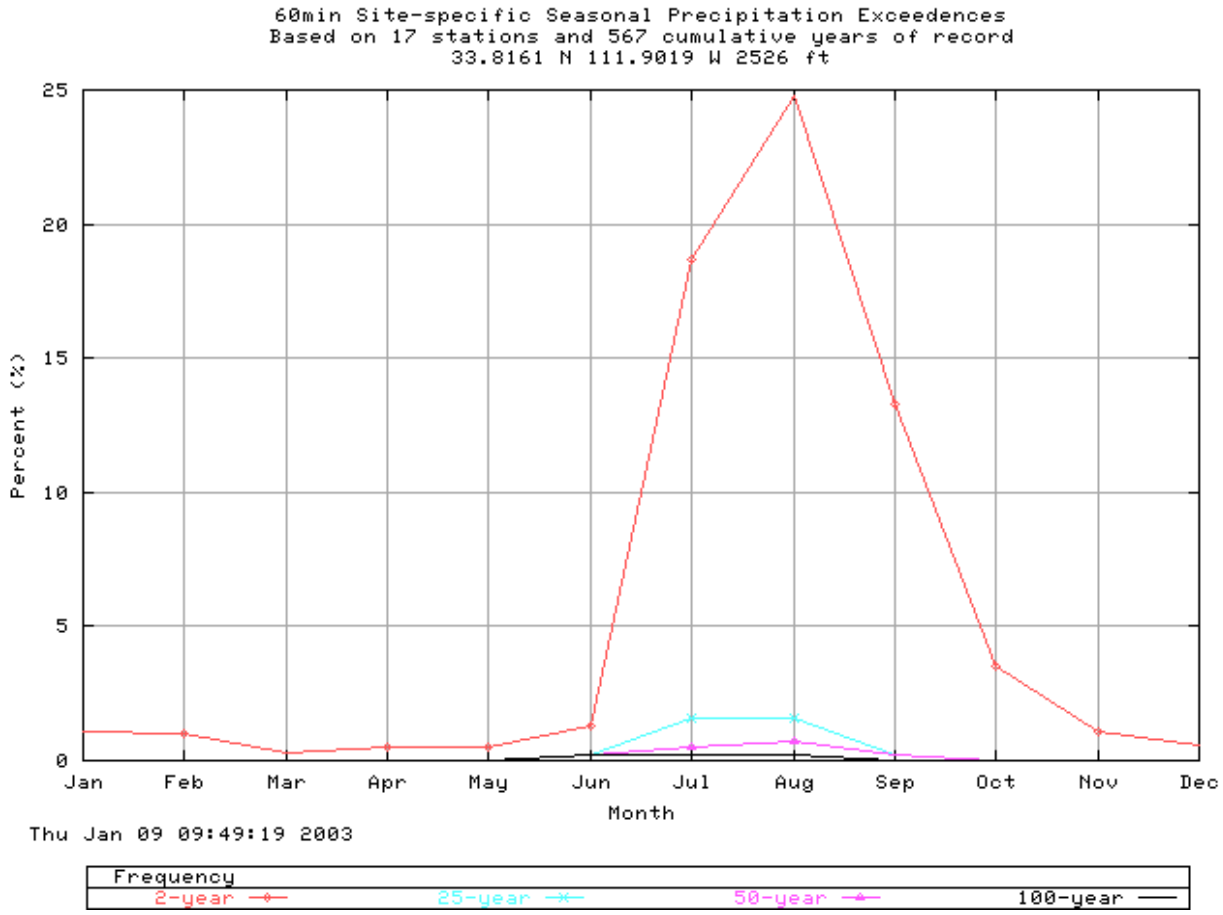
4.3 Seasonal Graphs

Seasonal information will be presented graphically as percentages of “exceedences” that occur in each month for a given region. “Exceedences” are events that exceed corresponding 2-year, 10-year, 25-year, 50-year, and 100-year precipitation frequency estimates at a given station and duration. The percentage is derived from the total number of cumulative years for all stations in a given region. Theoretically, 50% of the events should exceed the 2-year estimates, 4% should exceed the 25-year estimates, 2% should exceed the 50-year estimates and only 1% should exceed the 100-year estimates.

Exceedence graphs will be presented for the 1-hour, 24-hour, 48-hour and 10-day durations. Figure 2 is an example of an exceedence graph where extreme precipitation occurs primarily in July, August and September. The software for the 1-hour and 24-

hour durations has been written and preliminary graphs have been incorporated into the Precipitation Frequency Data Server. Work is nearly complete for the 48-hour and 10-day duration software.

Figure 2. Example of 60-minute seasonal exceedence graph.



4.4 Precipitation Frequency Data Server

In order to accommodate all of the PFDS and GIS compatible files, the allocated disk space for the PFDS was increased to 30 gigabytes. Our calculations suggest that this will be ample disk space to accommodate all of our current precipitation frequency projects.

The PFDS output was also modified to include links to regional "seasonal exceedence graphs" (see Section 4.6, Seasonal Graphs). The total number of stations and the total number of cumulative years used in the calculations are provided in the graph title.

4.5 Spatial Relations (Depth-Area-Duration Study)

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for area sizes of 10 to 400 square miles continues. The initial computer programming to quantify the spatial variation of storms used in the D-A-D analysis has been written, tested successfully, and performed on two study areas. The second phase of the programming to perform the actual D-A-D curve fitting is nearly complete and will be tested in January on two study areas. There has been no change in the D-A-D study areas that will be used to develop the final D-A-D curves (see previous progress report). Currently, there are 12 study areas scattered throughout the conterminous United States that have been quality controlled. Three other study areas may be added once the D-A-D curves are developed for the existing study areas. These three study areas will be used if it is determined that a single curve for the entire U.S. is insufficient and separate curves need to be developed.

5. Issues

5.1 Personnel Change

As of December 5, 2002, Eloisa Raynault resigned from HDSC. Eloisa was a civil engineer who was the project lead for the Ohio River Basin and Surrounding States Precipitation Frequency Study. A replacement will not be hired due to budget constraints. Debbie Todd will take on the responsibility of project lead for the Ohio River Basin Study. Unfortunately, Eloisa's departure has forced a delay in all project schedules.

6. Projected Schedule

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section.

Data Collection and Quality Control [March 2003]
Trend Analysis [April 2003]
Temporal Distributions of Extreme Rainfall [April 2003]
L-Moment Analysis/Frequency Distribution [April 2003]
Peer Review of Spatially Interpolated Point Estimates [June 2003]
Spatial Interpolation [July 2003]
Precipitation Frequency Maps [August 2003]
Web Publication [September 2003]
Spatial Relations (Depth Area Duration Studies) [February 2003]

6.1 Data Collection and Quality Control.

During the next quarter, the updates for the daily, hourly, and n-minute datasets will occur. The task involves data collection, formatting and quality control. Longer durations will be extracted upon the completion of the update and quality controlled. The complete update and quality control should take no longer than 4 weeks of working time.

6.2 L-Moment Analysis/Frequency Distribution.

A comprehensive L-moment statistical analysis will be done on all data and regions will be reassessed. The tasks involved with the precipitation frequency analysis will take roughly two months for the Puerto Rico and Virgin Islands study area.

6.3 Spatial Relations (Depth-Area-Duration Study)

Software development for the D-A-D computations will be completed in the next quarter and the computations will be performed for 12 study areas.

References

Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Weather Bureau Technical Paper No. 40*, U.S. Weather Bureau. Washington, D.C., 115 pp.

Hosking, J.R.M. and J.R. Wallis, 1997: *Regional frequency analysis, an approach based on L-moments*, Cambridge University Press, 224 pp.

Huff, F. A., 1990: Time Distributions of Heavy Rainstorms in Illinois, *Illinois State Water Survey*, Champaign, 173, 17pp.

Lin, B. and J.L. Vogel, 1993: A comparison of L-moments with method of moments, *Engineering Hydrology Symposium Proceedings*, ASCE, San Francisco, CA, July 25-30, 1993.

Miller, J.R., 1965: Two- to ten-day rainfall for return periods of 2 to 100 years in Puerto Rico and Virgin Islands. *Technical Paper No. 53*, U.S. Weather Bureau, Govt. Printing Office, Washington, D.C., 35 pp.

U.S. Weather Bureau, 1961: Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands. *Technical Paper No. 42*, U.S. Govt. Printing Office, Washington, D.C., 94 pp.